THE NATURAL SCIENCES IN ELEMENTARY EDUCATION.

In this closing decade of the XIXth century all thoughtful educators will doubtless agree that the great leading purpose of youthful education is a harmonious and all-sided development of the human capabilities; that the attainment of certain kinds of knowledge, which is the essential school means for developing the powers of the young, is useful only in so far as it coincides with the growth of power to use this knowledge in appropriate ways; that, therefore every desirable form of knowledge should be so presented as not only to insure its retention, but also to assure the exercise of the very powers it is fitted to develop,—that, in truth, acquisitions can be *vitalized* only by *method*; and finally, that a harmonious development of all the human capabilities will demand the *duly-proportioned* and *continuous* use in all classes of schools of means suited to develop efficiently in the child all these capabilities, and to enable him at the same time to sympathize intelligently with all the leading interests of his race.

The employments that may be used in schools fall into five somewhat natural groups, viz.: language, mathematics, the sciences of nature, history, and those exercises which like writing and drawing, singing and the use of tools, train the physical dexterities and react on taste. Each of these has its own special kind of truth, and its own special method of striving after it. Each rightly pursued trains the powers of the student in its own peculiar and salutary direction. Together they store the growing intelligence with knowledges which may gradually interact and combine to become *wisdom*, and to fit the mature man to grapple successfully with all the problems that life may present. Together also they correspond with the great currents of lively human interest. These then, together with those other subtle influences which shape character and in which studies rightly pursued only indirectly yet powerfully coöperate, are our school means for promoting a harmonious and all-sided development. All should be provided for by suitable representatives in every part of a well-constructed curriculum, from the lowest primary to the university where specialization properly begins.

It is no part of the purpose of this article to discuss the interesting question of the proper proportioning and arrangement of the several parts of a truly liberal education. This is a question which may well tax the powers of our wisest and most experienced school-men, as it is even now doing in Germany. What is essential to our present purpose is the idea of *unbroken continuity* in the use of every group of studies, but we must remember always that in the higher stages of advancement, the mathematics and physical dexterities, by becoming useful tools, may need less special attention.

So much has seemed necessary to be said in a general way that we may be properly oriented for the subject that we have immediately in view. For, if all groups of subjects should be represented in instruction, then the sciences of nature should not be neglected. If, for the purpose of insuring desirable intellectual habits, such instruction should be unbroken, then it becomes us to inquire, what portions of science may profitably be used in the most elementary classes, in what way these portions should be presented, and what aim should be kept steadily in view in such instruction.

But the first two of these inquiries can receive a satisfactory answer only when we have a clear idea of what the sciences of nature should contribute to the equipment of the completely developed man. Knowing this, we shall know for what the teacher should be held responsible in science-teaching. We shall have a definite purpose to attain, and shall thus be in a better position to select our means judiciously and to use them efficiently. Hence, as in all other teaching, so emphatically here, the question of *aim* to be gained must take precedence of all others; and it hardly admits of doubt that the unsatisfactory results of past science-teaching are due more largely to vague notions in this respect than to any other cause. Although animated instruction in science is pleasing to the young, its primary purpose is not merely to afford innocent pleasure. Although correct science-teaching opens wide fields of useful information, its chief purpose is not knowledge but the ability to gain knowledge, and therewith the ability and the disposition to be all one's life a learner.

Now all sciences of nature have their very foundation in correct and definite observation of the facts which nature presents. It is therefore of the very essence of science that the pupil should first

of all be taught to *observe*, to use his own senses directly upon appropriate objects and thus to increase their delicacy and power by repeated use ; and moreover, to give an account of what he has in any way experienced, that the fact of observation may be assured and that its results may be embodied in language. Unembodied knowledge, like disembodied spirit, is evanescent. But when even the youngest child is thus brought into direct contact with nature, he is quick to note the infinite variety which she presents, to see that this object is similar to that and quite unlike the other. Incipient powers of comparing and judging emerge, and should be appealed to in all possible ways ; for ripeness of judgment results only from repeated acts of judging. Rude and then more perfect classifications result from the grouping of the like and the separation of the unlike ; and the beginning of class notions is made, which future experience shall fill with ever clearer and more definite meaning, until gradually and almost unconsciously the pupil grows to a considerable mastery of the general and abstract terms which make so large a part of the language of the more enlightened members of his race. Even those larger operations, called generalization and induction from observed facts and phenomena, should have their definite beginnings in some part of the elementary course, and especially in certain easy and natural observations of physical phenomena. The youngster whose attention has a few times been directed to the flash of a distant gun and to the report which more tardily reaches his ear, can readily be brought to infer that sound travels more slowly than light, and to apply his generalization to lightning and the resultant roll of thunder.

Thus, it is obvious that the aim which the science teacher should keep ever clearly in view is first of all to train the senses to ever-growing accuracy and completeness in observation ; as accessory to this, to secure the expression and interpretation of what is observed ; to neglect no opportunities however slight for the exercise of judgment ; and to advance, gradually indeed, but always with definite purpose, towards the classification and generalization of results secured by direct personal observation. It will be observed that the key-note of the whole matter is *direct contact* with nature and diligent study of what she has to teach through the proper use of trained senses. Through these, important *vitalized centres*, or in Herbartian phrase, apperceiving

masses, are gradually formed to which all later acquisitions naturally gravitate, like to like. And when we consider how deeply the results of early habits of observation affect all the higher uses of the intellect, and how frequently through their lack the results of the highest intellectual and spiritual efforts are clouded by doubt or vitiated by error, we can but be surprised that so little definite attention has hitherto been given to this primal source of knowledge, and to the most effective means for its development, the elements of natural science.

The aim which we should strive to reach in elementary science-teaching being definitely determined, we come next to the consideration of the means that may be used. Here it will be found that a considerable latitude is afforded for choice, depending in part on what the locality most abundantly supplies, in part, and even more largely, on the tastes and acquirements of the teacher. In one place these circumstances may combine to dictate the study of plants, in another of insects or of other living higher animals, in another of minerals and rocks, and in still another of the objects of the sea, its pebbles, and its plant and animal life. In every place, the definite study is at hand and ought never to be neglected, of the relative position, direction, and distance of various local objects, which the Germans aptly call "knowledge of the home," as a key to the wider study of the globe on which we dwell. By the faithful and skilful use of any of these means extending over definite portions of the early school life, the powers of observing and judging may be efficiently trained, while a love for nature and the objects she presents may be inculcated which will not only foster the germs of good taste but also prove a great moral safeguard in the critical period of youth.

Of these various branches of the wide tree of science, it will probably be found that the study of plants will be the most widely available; furnishing objects everywhere attainable and interesting, affording the most abundant means for multiplied observations and easy comparisons suggestive of classification, and cherishing most directly a love for the beautiful in nature. Next in general availability to the study of plants is doubtless the observational study of minerals and rocks. Few places, even crowded cities, fail to supply abundant materials for such study to the ingenious and observant teacher; and where crystalline minerals can be obtained, they have the advantage of furnishing an

introduction through natural forms to the later study and description of geometric forms of which some city schools make use for training to habits of observation. A ground of preference of the two subjects here named over any of those involving the study of living creatures, may be found in the fact that they furnish no occasions for giving pain or uneasiness to animals, whilst they give a wide and harmless range for observation and comparison. Doubtless, at more advanced stages of the work of elementary schools, when pupils have become more considerate, and when careful training in observation and comparison has made them able to detect higher similarities amidst puzzling adaptive changes in structure, certain elementary zoological observations may with good teaching be made profitable. Yet beyond the barest elementary comparisons of the more obvious points of structure, such zoological studies may well be left to more advanced stages of progress than we are considering, and the attention of the more experienced pupils directed to the always attractive play of physical forces. In this, it need hardly be said, a great field is open for the highest skill of the teacher; for here, not only is observation to be exercised on phenomena rather than on objects; but generalization plays a larger part; with the occurrence of invariable sequences causal relations are to be traced; and amidst all the interplay of blind forces, the pupil is to be brought gradually to discern the reign of unchanging laws.

I am therefore inclined to recommend that in the elementary schools, attention should be confined to the observational study of plants, of minerals and rocks, of the local features which introduce to geography, and of the simplest and easiest phenomena of physics, with perhaps some structural study of the common animals. Where circumstances permit the study of all these, the observation of some of the more striking parts of plants, like leaves and flowers, may be begun with the youngest classes, may at some distance be followed and *alternated* with the examination of local characteristics and of minerals, and may in later stages of progress be succeeded by the elements of physics,—the elements of zoological structure occupying the latest place as demanding the greatest maturity of mind. Where but two can be used, they should be botany and physics, both of which admit of extended use without overpassing the growing powers of youth. Quite possibly in the schools of crowded cities, minerals and rocks,

succeeded by geometric forms, and then by physics, may do good service. Certainly, in at least one of the schools of Boston, the study of minerals has met with great success.

We come now to the important question, how to use the means which the various branches of natural science offer for the attainment of the end that has been proposed. And first and foremost, all useful teaching in the elements of science must be purely oral and observational, the teacher bringing the pupils into direct contact with nature and the objects that nature presents. Nothing like a text book should intrude; for such is the tendency of the human mind in school-rooms, that when text-books on such subjects enter, nature at once flies out of the window, and direct observation gives place to mere uninterested efforts of memory *about* nature. Books may indeed play a most useful part in confirming and aiding to correlate what has already been observed; but their only safe place is in grades beyond the elementary; and even there they need to be carefully watched, lest they usurp the place of both teacher and nature, and arrogate to themselves functions which do not at all belong to them. This last remark is true also of subjects other than scientific: in science it points to a source of positive danger. Hence let teachers of elementary science, in preparing their lessons, study carefully the objects they are to present, and glean useful hints from books, but let them when they enter the class-room leave all books behind.

A second suggestion which is of first-rate importance is this, that in the class-room the pupils, even the youngest, should make their own experiences, use their own senses, handle with their own fingers. To be sure at the outset they will be awkward and purblind. Practice only can make them acute and dextrous. At first they will see little save the most salient points. Questions brief and skilfully directed will guide them to still others, and interest will grow with that on which it feeds. The duty of the teacher here is to be the unobtrusive guide, the sympathetic friend, the wise suggester, while nature herself instructs. Such mere guidance is not always easy. The teacher is often tempted to *tell* the pupils what is plainly before their eyes. But don't. Wait a little, drop a suggestive question, show eager interest, and when your pupils have overcome the difficulty by their own efforts, both they and you will be repaid by their feel-

ing of growing confidence for future trials of their powers. What is told is apt to lack life and to slip soon away; what the child experiences remains. If something needs to be told,—and who can say that occasions for telling may not arise?—it should be told freely at the outset, and illustrated until the matter is brought clearly within the range of the child's experience; but it is well to consider carefully whether there is not a way in which the pupil may discover what would be told, by his own effort under proper guidance. What needs always to be borne in mind in this teaching is, that the pupils' ability to observe and judge can be developed to readiness and strength only by their own use of such powers, not by the teacher's ready use of his. One can as easily digest their food for them as train their senses and powers of comparison by any use save their own.

A third suggestion is that the child's ability to embody his sense-experiences and his efforts of judgment in appropriate language should keep even pace with his progress in these regards. When he has fully grasped some new fact, if the words of his present vocabulary will fitly express it, let him use them. If not, the essential new words should be given and written before him, and care should be taken that he uses them correctly both now and when future occasions arise. In this way alone can his ability to use with precision language, that peculiarly human instrument, keep pace with his intellectual growth. With regard to scientific terms, it may be said that, as they have been devised to express certain characters or facts with precision and brevity, it will probably be found expedient to use them frankly from the first, taking care always that the idea bring with itself the need of the word. When clear ideas are to be embodied, the young learn needful new words readily enough. The difficulty with scientific terms arises when they are presented without any fact to correspond to them. Properly introduced they will be found helpful rather than troublesome, and they will save pupils the inconvenience, in more advanced stages of progress, of changing from somewhat vague common words to terms more precise.

When pupils have learned to write and to draw with some degree of readiness, very effective means are afforded for assuring acuteness and definiteness of observation. "Writing," says Bacon, "maketh an exact man;" and when pupils attempt to delineate what they see, it will be found that vision penetrates

more deeply into the characters of objects and discerns those that are less obvious. Hence, they should be encouraged, if not required, to write about what they observe, in the form either of systematic lists of characters or of connected descriptions, and to resort to the pencil as another means of expression. Even somewhat more advanced pupils who have had no lessons in drawing show a surprising readiness in the use of the pencil when they see a useful purpose which it may subserve.

Written notes and careful drawings are an excellent preparation for the more advanced work in classifying numerous objects, to which the elementary work in botany should lead. It is obvious from what has already been said that definite and complete observation should precede every attempt at classification. Probably such work should begin by the separation of collections of objects, whether plants, minerals, or rocks, into groups based on their prominent observed characters, and the rectification of these groupings by a closer comparison of characters. When, however, the time comes for the use of manuals with analytical keys, great care will be needed that pupils first do their work of observing carefully and systematically, and advance as far in the classification as their knowledge will permit, before resorting to the manual. For example, in botany, if pupils have made a study of some member of the rose or lily family, they should thereafter be expected to need no table of analysis in the recognition of any new members of the same families. It may be remarked here that in botany the assignment of plants to their classes has the great merit of serving as a *test* of, and keeping an effectual check on, the thoroughness of our observation. A like advantage, but on the side of generalization, is presented in the case of physical science.

Finally, it will be found most serviceable in securing a healthy and enduring interest in natural history studies, and in training youth, to have their eyes and thoughts about them wherever they go, to encourage the making and arrangement of collections of natural objects. These collections may be for the school, in which case they should be so cared for as to express value ascribed to them, or they may belong to the collector. Children and youth have an instinct for collection; if they find nothing better, they gather postage-stamps or coins or even buttons: this craving may be turned to good account in the elementary study of nature; and,

if to this be added as an auxiliary, class excursions for the study of certain phases of nature, the strong social instinct will be enlisted in behalf of such study. German elementary schools, under less favorable conditions, find such excursions both feasible and instructive. Why may not also our schools?

Throughout this discussion, the competent teacher gifted with sound pedagogic sense has been assumed. A somewhat thorough previous acquaintance with the sciences of nature is of course desirable. Yet it is by no means impossible that an earnest and progressive teacher, thoroughly alive to the value of the kind of training here advocated, and disposed to do vigorous work, may fit himself by private observation and study, not only to give most useful lessons to young pupils, but also ultimately to do the highest work demanded by elementary schools. Such teachers will find some of our best summer schools very helpful. There are besides numerous elementary works to aid them by suggesting how to attack the problems that the study of nature presents. Several highly suggestive "Guides for Science Teaching," under the auspices of the Boston Society of Natural History, have recently been issued by D. C. Heath & Co. For the teacher of botany, Miss Youmans's "First and Second Books of Botany," with Gray's "Lessons," would be excellent, as also number two of the "Guides" just named. Numbers twelve and fifteen of the same "Guides" and Dana's "Manual of Mineralogy" would be very helpful in the study of minerals and rocks, to which may be added the first two chapters of Williams's "Applied Geology." For elementary physics, a recent work by Dr. Edward R. Shaw, entitled "Physics by Experiment," and the "Elements of Natural Philosophy" by Professor Cooley of Vassar would be valuable aids. In this brief list of books which would be suggestive to the teacher in preparing for his work it is not intended to give any preferred catalogue, but merely to name some of the helpful treatises that may readily be obtained. Doubtless, many others equally helpful and equally suggestive may be found. But it is important to remember that they are to be used only as helps, and by no means permitted to intrude upon the work in the elementary classroom. This work should be wholly oral and objective.

To recapitulate the positions of this article on the elementary teaching of natural science: (1) the teaching should be progressive and continue through the entire course of the elementary

schools with lessons as frequent as the relative importance of the subject demands: (2) its aim should be to assure habits of careful and definite observation, of comparison, and finally of classification and generalization: (3) the most available means are likely to be the study of plants, of local features, of minerals and rocks, and of the most interesting physical phenomena: (4) the work should be done through the direct observation of objects and phenomena, and without text-books; the pupils themselves should do the work under the wise and sympathetic guidance of the teacher, and embody its results in fitting language, oral or written, or in drawings; the work should lead ultimately to classification and easy generalizations; and throughout its course the making of collections, and field lessons and excursions will be very serviceable.

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